https://doi.org/10.1038/s44168-026-00346-6

Red flags in green promises: a framework for identifying greenwashing risk in corporate climate pledges

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As corporate net-zero pledges multiply, concerns about their credibility and potential for greenwashing are rising. This study is the first to develop a framework specifically tailored to assessing greenwashing in climate and net-zero pledges, combining disclosures, implementation plans, performance data, and lobbying activity, and to apply it at scale to more than 4000 companies. Using data from CDP, InfluenceMap, and the Net Zero Tracker, this analysis offers the largest empirical assessment of its kind. We identify greenwashing risk across seven dimensions, including missing interim targets, Scope 3 exclusion, offset reliance, and misaligned lobbying. We find 96% of pledging companies exhibit at least one risk indicator, with Scope 3 gaps, poor planning, and offsets most common. Greenwashing risk indicators are only weakly correlated, although higher target ambition is modestly associated with fewer red flags on some dimensions, such as Scope 3 coverage and lobbying. Sectoral and regional patterns also emerge, with lobbying-related risks less prevalent among European firms than elsewhere. Our approach advances the evidence base and supports stronger standards and oversight for corporate climate accountability.

Since the 2015 Paris Agreement and the Intergovernmental Panel on Climate Change (IPCC) established a benchmark of achieving "net-zero" carbon dioxide emissions by mid-century to prevent global temperature rise 1.5 °C above pre-industrial levels[1], national governments, city and regional authorities, financial institutions, and businesses have established their own decarbonization goals. These include not only long-term net-zero targets but also nearer-term climate pledges such as absolute and intensity-based emission reduction targets. As of September 2025, 1245 publicly listed companies from the Forbes Global 2000, 137 countries including the EU and Taiwan, 216 states and regions from the G20, and 337 cities with a population over 500,000 have pledged net-zero or equivalent long-term decarbonization targets[2]. These numbers reflect an increase of more than double in the number of entities since the Net Zero Tracker started evaluating the broader landscape of governments and businesses in 2020[3]. Despite this growing momentum of government and private entities (more broadly, non-state actors or NSAs) pledging net-zero commitments, concerns regarding their credibility have intensified[4,5], prompting the United Nations to convene an expert task force in 2021 to establish clear definitional criteria and standards for net-zero pledges[6].

Ongoing debate over net-zero targets, and climate pledges more broadly, arises from definitional ambiguities and differing interpretations, which, as[7] note, complicate assessments and fuel skepticism about their effectiveness and sincerity. A major point of contention revolves around the approaches used to achieve net-zero emissions. For instance, while some organizations set ambitious targets that include comprehensive emissions reductions across all scopes, encompassing direct and indirect emissions, others may focus narrowly on limited scope reductions or rely heavily on carbon offsets[8]. Many offsets rely on carbon removal efforts that may be non-permanent (e.g., forest-based conservation projects), overstated or ineffective[9]. The use of offsets to achieve net-zero targets and other climate claims has raised concerns about the integrity of pledges, as it can allow companies to maintain high levels of emissions while appearing to meet their targets superficially. A recent study revealed that 87% of the offsets used by companies to support their net-zero targets carry a high risk of failing to deliver genuine and additional emission reductions[10].

These questions surrounding the definitions and implementation of corporate climate pledges, including but not limited to net-zero targets, have prompted conclusions about the potential for greenwashing—defined as the practice of misleading stakeholders regarding the environmental practices or benefits of a company[11]. InfluenceMap, a non-profit thinktank that monitors corporate influence on climate policy, found that 58% of nearly 300 Forbes 2000 companies analyzed are at risk of greenwashing due to misalignment with support for government climate policy[12]. Lobbying activity is one potential indicator of greenwashing, but the existing literature

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lacks a universally agreed-upon definition of the term. Instead, it highlights the multidimensional nature of greenwashing, encompassing several key aspects. These include selective disclosure, where companies strategically present only positive information to create a misleadingly favorable public image; decoupling, which refers to the disconnect between symbolic corporate social responsibility (CSR) actions and substantive outcomes; and claim greenwashing, which contrasts misleading textual claims with discrepancies in actual execution[13].

To effectively address these complexities related to greenwashing, particularly in the context of net-zero and other climate pledges, we build upon prior frameworks for greenwashing detection[4,8,14–16] and emerging international standards for net-zero climate action[6,17]. From this literature, we identify the components most relevant to such climate pledges: comprehensive decarbonization across all emission scopes, prioritization of reducing own emission cuts over the use of offsets, and regularly publication of detailed progress and transition plans, among other requirements. If companies pledge net-zero or a climate commitment but then fail to meet any number of these criteria, we aim to determine if and how these indicators may suggest greenwashing practices or identify whether companies pledging net-zero may be at risk of greenwashing accusations.

Since our goal is to conduct a broad rather than small-*n* case analysis of potential climate pledge greenwashing, we utilize datasets that allow us coverage across as many companies as possible, including CDP, InfluenceMap, and the Net Zero Tracker. We contribute to the literature examining private climate governance and the role of large corporations in contributing to credible climate actions in the following ways: we develop a replicable framework for assessing climate claim credibility and potential greenwashing and provide a first, to our knowledge, empirical analysis of net-zero greenwashing predictors. Our dataset consists of 4131 companies distributed across multiple regions and industrial sectors (Fig. 1). Overall, we find that 87% or 3574 companies have made any type of climate claim. Analyzing the claims of those companies, we find that 96% or 3455 companies exhibit at least one indicator of net-zero or climate mitigation greenwashing based on our framework. We find that the incidence of greenwashing risk is prevalent across multiple regions and sectors, with most of the regions and sectoral breakdowns showing an incidence of the risk of greenwashing higher than 90%.

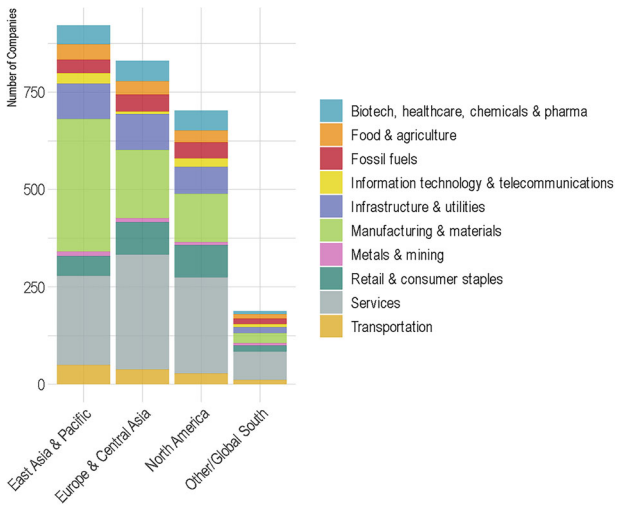

Fig. 1 | Regional and sectoral distribution of companies in our dataset ($n = 4131$). Companies in our sample are concentrated in East Asia and the Pacific ($n = 1252$), followed by Europe and Central Asia ($n = 935$) and North America ($n = 888$), with the Other/Global South group containing by far the fewest firms ($n = 283$). Across regions, the sector mix is dominated by manufacturing and materials and services, with infrastructure and utilities and retail and consumer staples making smaller but consistent contributions. All other sectors, including fossil fuels, food and agriculture, transportation, information technology and telecommunications, metals and mining, and biotech, healthcare, chemicals and pharma, represent comparatively minor shares.

Results

Incidence of greenwashing risk

Our dataset includes 3574 companies that made a climate pledge, with 1,622 or 45% making a net-zero or similar commitment, and the other 1952 or 55% making other types of climate commitments (see Table 1). Of the total sample, 96% exhibited at least one indicator of potential climate claim greenwashing based on our seven-dimension framework (See Methods and Table 2). The most common shortcoming was lack of Scope 3 emissions coverage, present in 70% of pledging companies. Other prevalent gaps included questionable use of carbon offsets (40%), no interim targets (21%), no implementation plan (18%), and lack of progress toward targets based on 2022 disclosure year data (20%). Additionally, 11% showed a disconnect between claiming to pledge net-zero or carbon neutrality but failing to comprehensively address all emission scopes, and 10% had a record of lobbying that contradicted their climate commitments. Examining the incidence of multiple greenwashing indicators, we observe that while 41% of companies evidence only one form of greenwashing, 12% of the companies in our database are at risk by at least 4 of the metrics. These findings highlight a widespread misalignment between public climate claims and concrete action.

We also explored the incidence of greenwashing risk for companies with explicit net-zero or similar targets (i.e., climate neutrality, GHG neutrality, etc.) and found that the overall incidence is very similar (95.8%). However, at the level of specific dimensions, patterns varied widely. For instance, questionable use of carbon offsets was 29 percentage points higher compared to the whole sample, and the share lacking an implementation plan is 10 percentage points higher. By contrast, lack of Scope 3 emissions coverage was 22 percentage points lower than the whole sample, and lack of progress toward targets was 5 percentage points lower. Overall, these results highlight that greenwashing risk is highly prevalent across all climate pledges analyzed, and that in some dimensions, particularly offsets and planning, it is more pronounced among firms with explicit net-zero commitments.

Greenwashing indicators are widespread across all regions. Companies in Europe and the Global South had the lowest prevalence of greenwashing risk (95%), with firms located in North America, and East Asia and the Pacific all exhibiting potential greenwashing at around 97% (Table 3).

Table 1 | Descriptions of company targets

Description of target	$N = 3574$[a]
1.5 °C target	9 (0.3%)
Absolute emissions target	2 (< 0.1%)
Carbon negative[b]	6 (0.2%)
Carbon neutral(ity)[b]	333 (9.3%)
Climate neutral[b]	51 (1.4%)
Climate positive[b]	7 (0.2%)
Emission intensity target	43 (1.2%)
Emission reduction target	1506 (42%)
GHG neutral(ity)[b]	1 (< 0.1%)
Net negative[b]	1 (< 0.1%)
Net zero[b]	1,144 (32%)
Other	403 (11%)
Science-based target	38 (1.1%)
Zero carbon[b]	12 (0.3%)
Zero emissions[b]	18 (0.5%)

[a]*n* (%). Includes only companies with at least one target.
[b]Climate Targets considered a b as Net-Zero claims.

Notably, North American firms had the highest rate of missing interim targets (34%) and the highest reliance on questionable offsets (55%) and negative lobbying (18%). On the other hand, companies in East Asia and the Pacific had the highest rate of missing Scope 3 emissions (78%), with Europe and Central Asia performing slightly better on this indicator. Our analysis of net-zero specific pledges shows a similar regional pattern to that of all climate pledges, but with higher incidence, and with slight differences in particular dimensions. For instance, questionable offset use is highest in East Asia and the Pacific (75%) and high in North America (74%).

In terms of sector (Table 4), fossil fuels and the metal and mining sectors stand out with the highest rate of greenwashing risk at 99% and 98%, respectively. For fossil fuel companies, they are driven by questionable offset use (71%) and anti-climate lobbying (57%). Metals and mining companies fail to cover Scope 3 or supply chain emissions in their targets (72%) and also have negative lobbying records (70%). Similarly high rates appear in transportation (97%) and biotech/pharmaceutical companies (97%). Information technology and services sectors also show strong signs of credibility gaps, particularly in offset use and lack of implementation plans. The retail and consumer staples and ICT sectors report the lowest greenwashing rates among industries, although both are still high at nearly 95%. One of the most consistent gaps across all sectors is limited Scope 3 coverage, with rates ranging from 58% to 82%, suggesting a systemic lack of accountability for value-chain emissions. Considering only companies pledging specifically net-zero, the pattern is similar: all sectors have very high incidence of any type of greenwashing, and Scope 3 coverage is the most consistent type of greenwashing risk across sectors.

Correlations between greenwashing indicators

To explore relationships between greenwashing indicators, specifically examining which indicators tend to co-occur with others, Fig. 2 displays two complementary visualizations. The chord diagram (panel a) illustrates raw co-occurrence counts, showing which indicators most frequently appear together across companies. The thickness of the connecting chords between greenwashing dimensions indicates the strength of these relationships. Scope 3 and offsets are among the most common co-occurring indicators, frequently appearing together with other categories such as plan and greenhouse gas coverage discrepancy (labeled as "Discrepancy"). Lobbying also shows frequent overlap with offsets and Scope 3, highlighting how strategic communication or influence efforts often accompany technical gaps in gas coverage or target-setting. The correlation heat map (panel b) adds a normalized perspective by displaying pairwise ϕ (phi) coefficients, which capture the direction and strength of the association of two indicators, relative to independence or no relationship. Some similar patterns emerge, such as Scope 3, offsets and lobbying clustering most strongly together, while some pairs (e.g., Scope 3 and interim targets) show weaker or even negative associations, suggesting that not all greenwashing indicators co-occur. Together, this figure reveals that while greenwashing often manifests through a single dimension, certain combinations, particularly involving Scope 3, offsets and lobbying, tend to cluster together, suggesting structural weaknesses in corporate climate pledges.

Table 2 | Summary of greenwashing indicators for all entities with a green claim for all claims (A) and for net-zero type of claims (B)

Company made a green claim but:	All claims (A) Percentage (%)	Net-zero claims (B) Percentage (%)
Has any potential sign of greenwashing	96.17%	95.8%
Has no interim target	20.82%	27.8%
Has no Scope 3 coverage	70.23%	48.3%
Has no plan	18.1%	28.0%
Has questionable offset use	40.24%	69.4%
Has discrepancy with gas coverage	11.19%	25.4%
Has negative lobbying record	10.27%	19.1%
Is not on track to achieve target	19.98%	14.4%

Determinants of greenwashing

We use the overall incidence of greenwashing in a multivariable logistic regression model (see Methods) to assess the likelihood that a company exhibits any potential greenwashing behavior as a function of its region, sector, target status, annual revenue, and two key variables regarding companies' pledges: target ambition and pro-rated target achievement (Table 5—Panel 1). In this model (the "any greenwashing" outcome), very few covariates are statistically significant. The only clear pattern is sectoral: firms in the information technology and telecommunications sector are much less likely than the reference group (biotech, healthcare, chemicals and pharmaceuticals) to display any of our greenwashing flags (OR = 0.13, $p < 0.05$). However, we do not find systematic associations between either higher ambition or better performance (pro-rated target achievement) and the odds of exhibiting any type of greenwashing once other factors are controlled for. We performe the same analysis for companies with net-zero targets and find similar results with limited systematic associations (Table 6). This limited structure in the "any greenwashing" outcome is consistent with our broader finding that each of the identified manifestations of greenwashing has its own characteristics and determinants.

To further examine firm-level drivers of greenwashing, we estimated models focusing on the likelihood of each specific greenwashing indicator (i.e., interim-target, Scope 3, plan, offset, gas coverage, lobbying, and progress greenwashing) (Table 5—Panels 2–8). These indicator-specific models reveal more structure and several notable patterns. In terms of climate planning, companies with targets that are underway or embedded in corporate strategy have a lower likelihood of lacking an interim target (OR = 0.12, $p < 0.05$) compared to targets that have already been achieved. As shown in Fig. 3, this finding is not surprising, given that already "achieved" targets tend to be much less ambitious, with only an average of 22% aimed

Table 3 | Summary of greenwashing indicators for all entities with a green claim by region

Region	East Asia and Pacific	Europe and Central Asia	North America	Other/Global South
Company made a green claim but:				
Has any potential sign of greenwashing	97.31%	94.62%	97.04%	94.93%
Has no interim target	16.14%	15.63%	34.24%	23.55%
Has no Scope 3 coverage	78.01%	66.64%	62.44%	73.91%
Has no plan	14.40%	12.77%	31.87%	15.94%
Has questionable offset use	36.71%	34.79%	55.69%	32.61%
Has discrepancy with gas coverage	9.97%	11.51%	13.27%	9.06%
Has negative lobbying record	7.36%	8.07%	17.89%	9.78%
Is not on track to achieve target	26.98%	16.64%	13.39%	22.46%

Table 4 | Summary of greenwashing indicators for all entities with a green claim by sector

Industry Sector	Biotech	Food	Fossil Fuels	ICT	Infra.	Manu.	Metals	Retail	Services	Transport
Company made a green claim but:										
Any potential greenwashing	96.98%	95.89%	99.31%	94.74%	94.74%	96.53%	98.00%	94.62%	94.99%	96.86%
Has no interim target	26.63%	20.5%	27.78%	25.44%	16.03%	13.76%	12.00%	19.71%	33.87%	19.50%
Has no Scope 3 coverage	64.32%	69.86%	60.42%	57.89%	65.60%	82.02%	72.00%	61.29%	59.42%	64.15%
Has no plan	22.61%	17.12%	30.56%	16.67%	15.74%	10.62%	18.00%	21.15%	29.29%	11.95%
Has questionable offset use	51.76%	31.51%	71.53%	41.23%	46.36%	25.24%	46.36%	43.01%	56.55%	45.91%
Has Discrepancy with gas coverage	9.55%	7.53%	15.28%	12.28%	10.79%	5.74%	14.00%	13.62%	19.49%	10.06%
Has negative lobbying record	20.10%	2.05%	56.94%	29.82%	17.20%	3.47%	70.00%	7.17%	0.53%	35.85%
Is not on track to achieve target	23.62%	30.82%	20.83%	26.32%	20.41%	23.40%	20.00%	16.49%	11.61%	16.98%

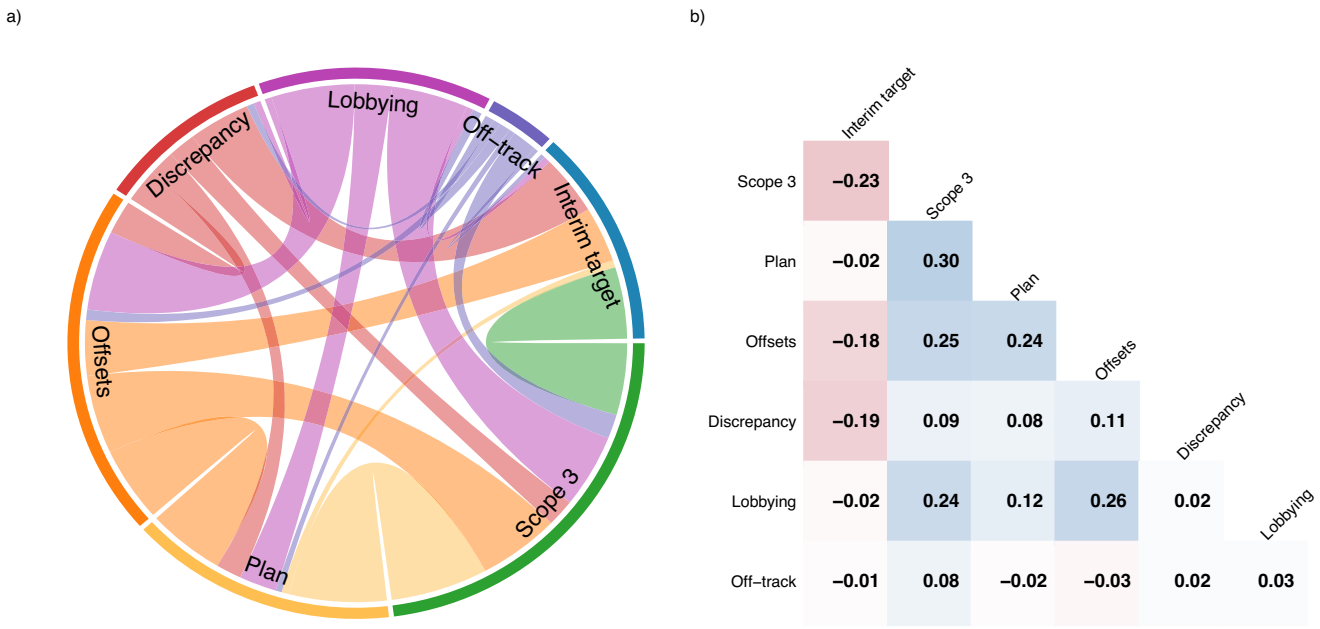

Fig. 2 | Co-occurrence and correlations among end-target integrity indicators. **a** Chord diagram displaying correlations between different greenwashing risk indicators, where the thickness of the connecting bands reflects the frequency with which two indicators co-occur across companies; **b** pairwise ϕ (phi) correlation coefficients between indicators, where positive values correspond to indicators that tend to appear together, where negative values suggest they are less likely to occur together. The strongest positive associations are between Scope 3 and plans ($r = 0.30$), offsets and lobbying ($r = 0.26$), and Scope 3 and offsets ($r = 0.25$), while interim targets are negatively associated with Scope 3 ($r = -0.23$), discrepancy ($r = -0.19$), and offsets ($r = -0.18$); off-track shows near-zero correlations with most other indicators.

reduction compared to targets that are underway (45%) or newly declared (44%). Higher annualized ambition is also associated with lower odds of Scope 3 greenwashing (OR = 0.83, $p < 0.05$) and lobbying greenwashing (OR = 0.76, $p < 0.05$), although pro-rated target achievement is not significantly related to any individual indicated. Annual revenue appears statistically significant in several models, including those for plan, offset, and gas-coverage greenwashing ($p < 0.05$), but the odds ratios round to 1.00, indicating that the substantive effect is negligible.

For the lobbying indicator, we find that companies based in Europe are less likely to be at risk of greenwashing through lobbying than firms in East Asia and the Pacific (OR = 0.22, $p < 0.01$), whereas we do not detect statistically significant regional differences for North America or other regions. Sectoral patterns are pronounced: firms in the information technology and telecommunications sector (OR = 0.22, $p < 0.05$), retail and consumer staples (OR = 0.05, $p < 0.001$), and services (OR = 0.14, $p < 0.05$) have notably lower odds of lobbying-related greenwashing relative to the reference sector, while transportation firms exhibit substantially higher odds (OR = 6.33, $p < 0.05$). Together, these results underscore that different dimensions of greenwashing are driven by distinct combinations of regional, sectoral and target-design characteristics, indicating that no single measure can fully capture greenwashing risk.

The analysis of greenwashing risk determinants for net-zero pledges reveals some complementary insight for this particular group of companies (Table 6). We observe that companies headquartered in Europe show lower odds of using questionable offsets (OR = 0.31, $p < 0.01$), lobbying (OR = 0.32, $p < 0.04$) and lack of progress (OR = 0.11, $p < 0.001$). On the contrary, companies in North America show higher odds of lobbying (OR = 3.89, $p < 0.001$). From a sectoral perspective, fossil fuel (OR = 6.54, $p < 0.05$) and transportation (OR = 9.97, $p < 0.05$) companies show higher odds of greenwashing compared to the reference sector, whereas the retail and consumer sector shows lower odds of lobbying (OR = 0.08, $p < 0.001$). Finally, looking at ambition, we also observe that more ambitious companies have lower odds of lobbying (OR = 0.79, $p < 0.05$). Overall, restricting the analysis to companies with a net-zero target yields a complementary picture of the determinants of greenwashing that is broadly consistent with the full-sample model.

https://doi.org/10.1038/s44168-026-00346-6

Table 5 | Regression results examining determinants of corporate greenwashing

Variable	Any greenwashing *N* = 1251		Interim target greenwashing *N* = 284		Scope 3 greenwashing *N* = 292		Plan greenwashing *N* = 272		Offset greenwashing *N* = 265		Gas coverage greenwashing *N* = 272		Lobbying greenwashing *N* = 292		On track greenwashing *N* = 297	
	Odds ratio[a]	SE	*Odds ratio*[a]	SE	*Odds ratio*[a]	SE	*Odds ratio*[a]	SE	*Odds ratio*[a]	SE	*Odds ratio*[a]	SE	*Odds ratio*[a]	SE	*Odds ratio*[a]	SE
Region																
East Asia and Pacific	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Europe and Central Asia	0.09	0.112	1.33	0.608	**0.40***	0.165	0.97	0.468	0.72	0.406	1.30	0.643	**0.22****	0.118	**0.10*****	0.050
North America	0.10	0.116	0.94	0.392	0.49	0.187	1.75	0.725	0.74	0.402	0.86	0.406	2.61	1.28	**0.28****	0.110
Other/Global South	0.66	1.13	1.94	1.46	**0.06****	0.064	0.28	0.276	0.53	0.485	0.63	0.558	5.83	6.18	0.33	0.230
Current status of target																
Achieved	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Underway	0.35	0.440	**0.12***	0.119	0.17	0.156	1.04	1.01	6.50	8.57	0.26	0.256	0.62	0.715	0.76	0.657
New	1.08	1.80	0.36	0.399	0.28	0.282	4.31	4.57	**60.7***	109	0.24	0.271	0.55	0.699	0.90	0.860
Other	0.54	0.968	0.08	0.147	2.10	2.79							2.22	4.21	0.24	0.412
No end target	0.04	0.064	0.09	0.189	0.22	0.317	1.68	3.60	1.63	3.70	0.33	0.717	1.43	3.11	6.18	10.0
Annual revenue	1.00	0.000	1.00	0.000	1.00	0.000	**1.00****	0.000	**1.00***	0.000	**1.00****	0.000	1.00	0.000	1.00	0.000
Sector																
Biotech	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Food and agriculture	1.02	1.41	3.28	4.18	0.16	0.256	16.3	27.4	0.41	0.733	3.84	6.69	0.16	0.273	4.09	5.22
Fossil fuels	0.84	0.897	0.67	0.402	0.48	0.247	0.54	0.334	0.26	0.237	2.75	2.09	3.53	2.55	1.74	1.05
ICT	**0.13***	0.126	2.52	1.51	0.37	0.209	1.96	1.20	0.49	0.470	3.22	2.60	**0.22***	0.155	0.64	0.420
Infrastructure	1.43	1.51	0.34	0.222	0.83	0.401	0.36	0.216	3.90	4.56	0.80	0.661	**0.26***	0.157	0.64	0.379
Manufacturing	11.9	17.3	2.44	1.70	0.81	0.510	1.66	1.15	0.25	0.264	0.74	0.828	1.10	1.02	0.28	0.271
Metals and mining	0.36	0.560	0.51	0.395	1.27	0.848	0.44	0.338	**0.09***	0.097	3.06	2.65	1.80	1.79	1.61	1.09
Retail	1.10	1.05	0.55	0.357	**0.32***	0.179	1.24	0.746	1.43	1.39	3.83	30.04	**0.05*****	0.034	0.69	0.463
Services	16.1	20.8	2.89	2.42	0.47	0.383	1.48	1.33	**0.11***	0.123	6.42	6.36	**0.14***	0.129	0.09	0.138
Transportation	2.10	3.13	1.33	0.822	**−0.21***	0.132	0.23	0.183	0.19	0.187	1.60	1.40	**6.33***	6.25	0.26	0.218
Annualized ambition	0.81	0.084	0.98	0.082	**0.83***	0.070	0.98	0.088	0.89	0.100	0.95	0.088	**0.76***	0.078	1.00	0.059
Pro-rated emissions target achievement	0.73	0.068	0.94	0.091	0.91	0.078	0.86	0.099	1.01	0.143	1.04	0.109	0.90	0.106		
Ambition*PETA	1.03	0.033	0.99	0.033	1.03	0.032	1.05	0.036	1.05	0.047	1.02	0.034	1.01	0.040		
LobbyMap score of C or lower			1.15	0.466	1.00	0.356	**2.26***	0.935	**4.49****	2.40	1.41	0.620			0.74	0.319

SE standard error.

[a]*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

https://doi.org/10.1038/s44168-026-00346-6

Table 6 | Regression results examining determinants of corporate greenwashing for net-zero claims only

Variable	Any greenwashing *N* = 678		Interim target greenwashing *N* = 256		Scope 3 greenwashing *N* = 256		Plan greenwashing *N* = 252		Offset greenwashing *N* = 245		Gas coverage greenwashing *N* = 252		Lobbying greenwashing *N* = 256		On track greenwashing *N* = 261	
	Odds ratio[a]	SE	Odds ratio[a]	SE	Odds ratio[a]	SE	Odds ratio[a]	SE	Odds ratio[a]	SE	Odds ratio[a]	SE	Odds ratio[a]	SE	Odds ratio[a]	SE
Region																
East Asia and Pacific	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Europe and Central Asia	0.14	0.168	1.45	0.711	**0.31****	0.136	0.85	0.463	0.82	0.469	1.22	0.608	**0.32***	0.175	**0.11*****	0.056
North America	0.16	0.185	0.70	0.315	0.49	0.194	1.95	0.870	0.89	0.489	0.88	0.416	**3.89***	2.03	**0.33****	0.135
Other/Global South	0.82	1.45	1.31	1.11	**0.08****	0.085	**0.05***	0.078	0.52	0.485	0.66	0.608	2.42	2.97	**0.22***	0.169
Current status of target																
Achieved	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Underway/in corporate strategy	0.40	0.638	**0.07****	0.082	0.19	0.183	0.69	0.710	4.13	5.50	0.37	0.373	0.09	0.108	0.52	0.500
New/declaration/pledge	1.24	2.39	0.28	0.325	0.34	0.364	3.70	4.14	**41.0***	73.8	0.32	0.362	0.10	0.127	0.63	0.661
Other	0.66	1.53	0.10	0.196	7.93	14.8							0.15	0.309	0.31	0.588
No end target	0.06	0.144	0.11	0.244	0.16	0.344	1.07	2.39	2.89	6.59	0.40	0.865	0.15	0.358	4.87	10.1
Annual revenue	1.00	0.000	1.00	0.000	1.00	0.000	**1.00****	0.000	**1.00***	0.000	**1.00****	0.000	1.00	0.000	1.00	0.000
Sector																
Biotech, healthcare, chemicals and pharma	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Food and agriculture	1.03	1.56	1.16	2.04	0.40	0.684	4.83	8.40	0.23	0.432	3.95	7.13	0.14	0.254	9.01	15.5
Fossil fuels	1.35	1.48	0.50	0.335	0.54	0.315	0.45	0.298	0.32	0.299	2.77	2.11	**6.54***	4.99	1.50	0.949
Information technology and telecommunications	0.31	0.309	**3.62***	2.37	0.44	0.271	1.95	1.28	0.58	0.560	3.97	3.23	0.34	0.244	0.53	0.360
Infrastructure and utilities	2.26	2.47	0.30	0.216	1.00	0.529	**0.26***	0.161	3.83	4.48	0.77	0.638	0.43	0.272	0.51	0.312
Manufacturing and materials	10.0	15.4	1.68	1.42	1.16	0.879	1.16	0.916	0.15	0.158	0.89	1.01	2.32	2.52	0.31	0.311
Metals and mining	0.48	0.760	0.44	0.356	1.48	1.10	0.39	0.314	**0.10***	0.108	2.89	2.50	9.25	13.9	1.75	1.27
Retail	1.67	1.70	0.47	0.355	0.37	0.228	0.55	0.368	1.27	1.24	4.14	3.31	**0.07*****	0.049	0.48	0.343
Services	18.8	24.7	3.61	3.15	0.59	0.508	1.30	1.20	0.12	0.136	6.00	5.95	0.26	0.248	**0.07***	0.117
Transportation	3.12	4.71	1.60	1.07	**0.26***	0.180	**0.19***	0.159	0.21	0.215	1.50	1.31	**9.97***	10.3	0.25	0.209
Annualized ambition	0.81	0.086	0.95	0.086	0.85	0.075	0.98	0.100	0.86	0.097	0.95	0.088	**0.79***	0.079	1.01	0.062
Pro-rated emissions target achievement	0.75	0.092	0.91	0.093	0.93	0.087	0.88	0.109	0.96	0.131	1.03	0.108	0.95	0.117		
Ambition*PETA	1.02	0.031	0.99	0.036	1.02	0.033	1.06	0.040	1.06	0.047	1.02	0.035	0.98	0.038		
LobbyMap score of C or lower			1.41	0.633	0.76	0.289	2.32	1.06	**4.00***	2.26	1.51	0.679			0.62	0.286

SE standard error.

[a]*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

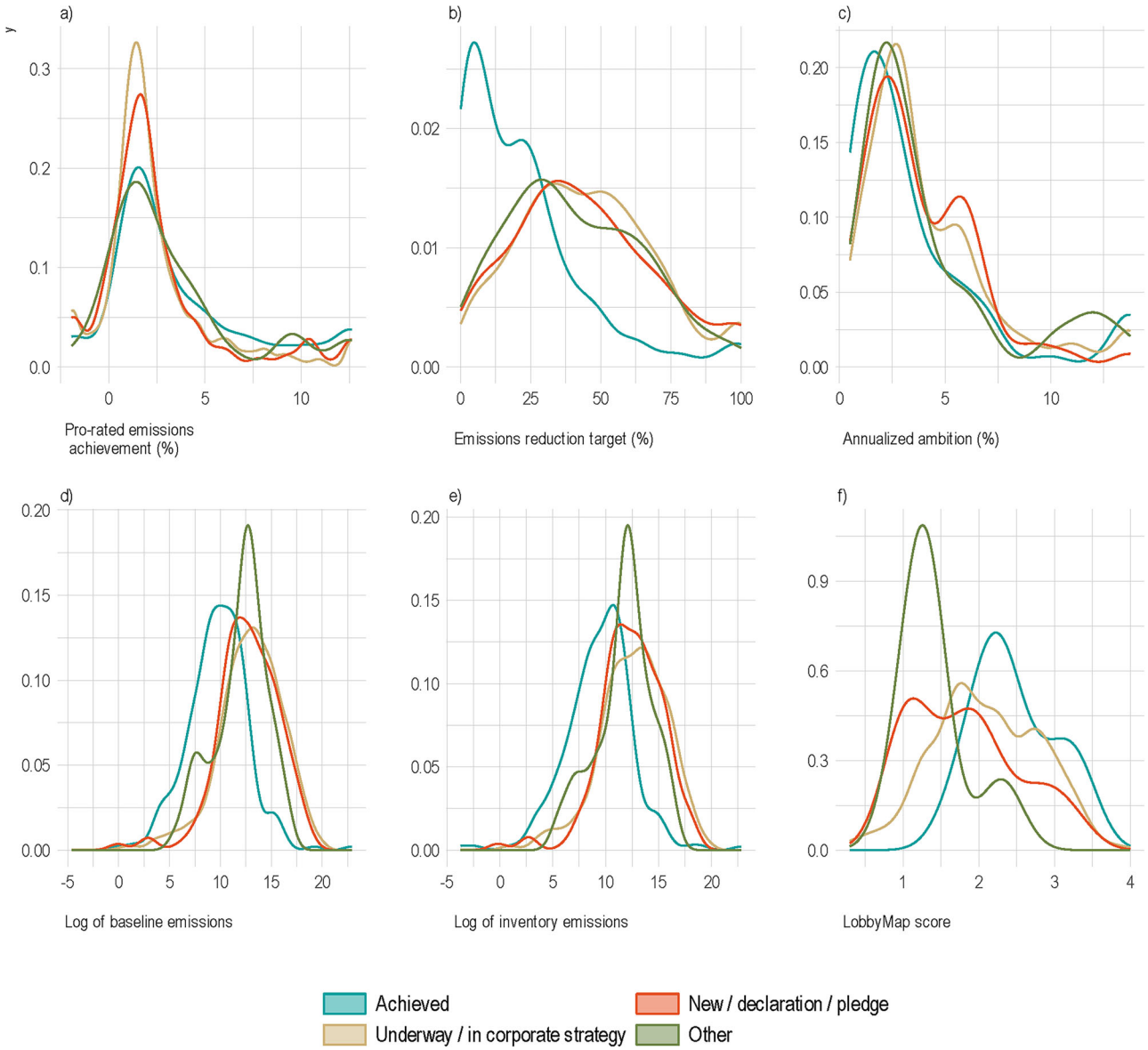

Fig. 3 | Distribution of ambition, emissions and progress by companies' end-target status. a–f Compare kernel density distributions of six metrics across companies grouped by end-target status (Achieved; Underway/in corporate strategy; New/declaration/pledge; Other). Firms with Achieved targets tend to show lower stated reduction targets and lower baseline and inventory emissions, while New and Underway targets concentrate at mid-range reduction targets and higher logged emissions. Annualized ambition is generally concentrated at low single-digit rates across target statuses. LobbyMap scores are shifted higher (0 = F; 1 = D; 2 = C-; 3 = B-; 4 = A-; therefore the higher scores the better the LobbyMap rating) for Achieved companies, whereas "Other" target status clusters at lower scores.

Predicted probabilities

To aid in interpreting our results, we also calculate the predicted probabilities of each type of greenwashing for hypothetical firms, described by the most frequent categorical attributes in our sample (Table 7). For the overall incidence model, the predicted probability of exhibiting at least one type of greenwashing is greater than 99% for all combinations of revenue, ambition, and target achievement we consider, indicating that these characteristics make essentially no difference whether a firm has any red flag. Differences are more apparent when we focus on specific greenwashing risk indicators. More ambitious firms are less likely to greenwash in the models where it was a statistically significant variable. As ambition increases from 2.5th to 97.5th percentile, the probability of Scope 3 greenwashing falls from 57% to 17%, and the probability of lobbying greenwashing falls from 95% to 43%.

Higher-revenue firms have lower probabilities of engaging in some types of greenwashing. Revenue accounts for the largest drop in probability for our plan greenwashing and gas coverage discrepancy greenwashing models. Compared to companies at the 2.5th percentile of revenue, which our model predicts have a 53% and 79% chance of engaging in these types of greenwashing, respectively, a company earning 97.5th percentile revenue has a 20% and 40% chance of doing so. Regarding the offset greenwashing outcome, companies in the 97.5th percentile of revenue see a 9-percentage point reduction in the probability of this type of greenwashing compared to companies in the 2.5th percentile (from 21% to 12%).

Discussion

Greenwashing is widely acknowledged as a problem in corporate sustainability, yet its lack of a multi-dimensional and clear operational definition has made it difficult to identify effectively. Existing literature recognizes greenwashing as a multifaceted phenomenon[16], ranging from selective disclosure to symbolic action and misleading claim, but the term often remains too broad to apply meaningfully in specific contexts. Our framework addresses this concern, by clearly identifying and operationalizing ways in which greenwashing can manifest in climate pledges, including a

Table 7 | Predicted probabilities

Percentile	2.5th	97.5th	Difference	2.5th	97.5th	Difference	2.5th	97.5th	Difference
Predicted probability of greenwashing:[a]	Revenue			Ambition			Pro-rated target achievement		
Any potential greenwashing	99.993%	99.991%	*0.0000*	99.995%	99.957%	*−0.0004*	99.997%	99.909%	*−0.0009*
Interim target	39.625%	42.663%	*0.0304*	42.230%	31.012%	*−0.1122*	47.418%	21.222%	*−0.2620*
Scope 3	48.130%	48.284%	*0.0015*	57.478%	17.517%	*−0.3996*	48.589%	46.839%	*−0.0175*
Plan	53.3120%	19.858%	*−0.3345*	46.214%	66.918%	*0.2070*	50.625%	50.339%	*−0.0029*
Offset	21.174%	11.941%	*−0.0923*	21.498%	16.329%	*−0.0517*	11.766%	63.009%	*0.5124*
Gas coverage	79.823%	39.727%	*−0.4010*	78.690%	73.238%	*−0.0545*	71.300%	90.233%	*0.1893*
Lobbying	91.260%	90.062%	*−0.0120*	95.283%	42.662%	*−0.5262*	93.018%	83.139%	*−0.0988*
On track	10.182%	7.331%	*−0.0285*	9.931%	10.006%	*0.0008*			

[a]For a company with modal values of each categorical variable (located in East Asia or the Pacific, with a target underway or in corporate strategy, and in the Services sector) and median values of other numeric variables.

deep-dive in net-zero commitments which are now central to corporate climate strategies[15,18]. These commitments, particularly net-zero, often involve long time horizons, heavy reliance on carbon offsets, and incomplete emissions accounting, making them especially vulnerable to greenwashing risk. Through the seven indicators we examined, we find that companies display different constellations of potentially concerning practices, including the absence of interim targets, omission of Scope 3 emissions, or heavy reliance on questionable offsets.

Rather than delivering a single precise measure of "true" greenwashing, our framework therefore highlights the inherently multi-dimensional context-dependent character of misleading climate claims. Our analysis reveals that potential greenwashing in climate pledges is a global phenomenon, with more than 96% of all companies (at least 94% of entities in all regions, see Table 2) exhibiting at least one red flag based on our framework. We also observe that net-zero types of targets show a higher incidence of this behavior for all aspects identified, except on Scope 3 coverage and insufficient performance. This widespread misalignment between corporate climate claims and actual practices indicates that greenwashing is not confined to particular sectors or regions but represents a systemic issue in private climate governance. This interpretation is reinforced by findings from[19], who show that firms often face few consequences even when their climate targets quietly disappear. While the prevalence of red flags is near-universal, the marginally better performance observed in Europe (94% compared to >97% in other regions) may reflect recent regulatory efforts by the European Union to rein in misleading climate claims. Already, at least 10 jurisdictions, including Australia, Canada, China, the European Union, France, Hong Kong, Singapore, South Korea, the United Kingdom and the United States, have introduced legislation or mandates to curb greenwashing and misleading environmental claims[14]. Initiatives such as the "Empowering Consumers for the Green Transition" Directive (Directive (EU) 2024/825)[20] and Canada's Competition Act, following Bill C-59[21] aim to close the credibility gap by banning unverified environmental assertions, requiring independent verification, and introducing enforceable penalties.

These emerging regulatory frameworks not only include requirements for climate-related disclosure, but also place increasing emphasis on the quality of firms' targets (for example, requiring the coverage of Scope 3 emissions, the inclusion of interim milestones, and the credibility of transition plans). Evidence from the United Kingdom suggests that mandatory climate disclosure and reporting can improve corporate climate performance: companies subject to such requires tend to reduce emissions more than unregulated firms[22,23]. Researchers also found that mandatory reporting has curbed greenwashing by reducing the embellishment, overoptimism, and ambiguity in disclosures[24]. Our study cannot directly assess the impact of disclosure mandates per se, but it complements this literature by examining how variation in target design relates to specific dimensions of greenwashing. We do not find that better pro-rated progress towards emission reduction targets is systematically associated with lower odds of greenwashing. However, higher annualized ambition is associated with lower odds of certain flags, particularly omissions of Scope 3 emissions and misaligned lobbying, the latter being true also for all companies and for those that have net-zero pledges. In quantitative terms, our predicted probabilities suggest that more ambitious firms are only modestly less likely to exhibit certain red flags for Scope 3 and interim target greenwashing. These results suggest that stronger target design may coincide with fewer integrity problems on some fronts, even though disclosure and progress alone are insufficient to eliminate greenwashing risk.

While previous research has highlighted the contradiction between public climate pledges and obstructive lobbying as a form of greenwashing[25], our findings suggest that negative climate lobbying is also associated with weaknesses in other dimensions of firms' climate plans. Companies flagged for obstructive lobbying—those receiving a "C" rating or lower from LobbyMap—are more likely to lack formalized climate plans or rely on questionable use of offsets, indicating a broader pattern of weak implementation behind stated commitments. We also find that lobbying-related greenwashing is significantly less common among firms headquartered in Europe and Central Asia than among those in East Asia and the Pacific, whereas differences for North America and other regions are imprecisely estimated. However, looking at companies with net-zero pledges, we observe that, in addition to the lower odds for European companies, organizations based in North America have significantly higher odds of negative lobbying compared to East Asia and the Pacific. These patterns are consistent with the concern that negative lobbying activities can undermine the development and enforcement of effective climate disclosure and target-setting regulations, thereby weakening accountability mechanisms and enabling ongoing greenwashing. In particular, trade associations often serve as intermediaries, allowing firms to indirectly oppose progressive climate policies while preserving a public-facing image of sustainability[26]. Membership in these associations can obscure corporate greenwashing by creating a disconnect between firms' climate pledges and the actions of the groups representing them.

To our knowledge this study is the first to provide cross-sectoral, multi-country and large-scale empirical evidence of climate greenwashing, leveraging both self-reported and expert-tailored datasets such as the Corporate Disclosures from CDP, LobbyMap, and the Net Zero Tracker database. While our large-N approach necessarily involves some coding simplifications, our findings align with other earlier, smaller-scale studies at the sectoral or national level that identified similar patterns of misalignment between corporate claims and actions[27–30]. While it is not yet possible to similarly assess the prevalence and determinants of greenwashing in other aspects of sustainability, the general framework proposed and the operationalization can serve as important starting points for future studies. Moving forward, future refinements could move beyond binary measures

towards graded or intensity-based indicators that capture the depth of disclosure (e.g., degree of Scope 3 coverage). For example, since these Scope 3 emissions are more material for fossil fuel or car manufacturers than for service-oriented firms, their omission is more consequential, and greenwashing assessments should take these differences into consideration. We expect that by leveraging the capacity of climate-specific large-language models (LLM) to retrieve environmental information from ESG reports[31], further greenwashing indicators could be consistently operationalized leading to further analysis and scrutiny on corporate entities.

Our study is certainly not without its limitations. First, greenwashing is a complex and evolving phenomenon, and our framework certainly does not capture the full range of corporate behaviors intended to mislead the public about climate-related performance. By focusing on a conservative set of seven measurable indicators, aligned by several international initiatives such as the UN's Integrity Matters (2022)[6], Race to Zero (2022)[32], SBTi's Corporate Net-zero standard (2024)[33] and ISO's Net Zero Guidelines (2022)[17], our approach operationalizes what these efforts treat as core integrity conditions for credible climate pledges (e.g., interim targets, Scope 3 coverage, credible plans, limits on offsets, etc.). While these indicators do not exhaust all possible forms of greenwashing, they capture the main elements emphasized by these current standards and mainstream approaches. The fact that almost all of the pledging companies in our sample fail on at least one of these dimensions does not imply that all companies are necessarily nefariously greenwashing. Rather, our results more likely suggest that corporate net-zero governance is still at an early stage, with many pledges potentially announced before detailed guidance and enforcement mechanisms were in place. As emerging standards and regulations tighten, we would expect some of these red flags to diminish.

Second, data limitations introduce challenges. Detailed information about performance, as well as some nuances of firms' Scope 3 emissions or carbon credits and offsets, are not available for a large number of organizations, and are explored in smaller sample studies such as Corporate Climate Responsibility Monitor[4]. Matching across disparate datasets (CDP, Net Zero Tracker, and LobbyMap) was complicated by inconsistencies in company naming, corporate restructuring (e.g., mergers, subsidiaries), and differing sample sizes across sources. Additionally, because our emissions and target data are primarily self-reported (i.e., to CDP), they are subject to potential biases and reporting gaps. These data constraints also limit our ability to control for the specific climate policies to which each company is subject; and, although our regression models include region fixed effects based on firms' headquarters, which to some extent proxy for this variation in policy, they cannot capture the full set of regulations that apply to firms' global operations, nor subnational or sector-specific policy variation, since companies may operate across many jurisdictions and CDP does not provide comprehensive information on the geographic distribution of reporting companies' facilities. Our analysis also does not fully account for companies that have not made any public climate commitments, since our entire CDP dataset was composed of companies who were pledging some type of emission reduction target, and does not account for companies failing to take action. While the Net Zero Tracker does evaluate the entire set of Forbes Global 2000 companies, we lack detailed information beyond these largest publicly-listed companies, including large privately-listed firms where data are not as readily available. Time series data is also largely unavailable for most of the indicators, preventing an analysis that could consider performance and target maturity. Despite these limitations, our framework provides a starting point for identifying red flags in corporate climate claims and our large-scale analysis is a first step in quantifying the pervasiveness of greenwashing risk at scale.

As climate commitments and net-zero pledges become central to corporate climate strategies, ensuring the credibility of these commitments is more urgent than ever. Our analysis demonstrates that greenwashing risk is both widespread and measurable, with the vast majority of companies exhibiting at least one indicator of misalignment between their climate claims and actions. By developing a multi-dimensional, indicator-based framework focused on climate commitments including net-zero pledges, we provide a replicable method for identifying red flags and to map where closer scrutiny may be warranted, rather than a singular measure of "true" greenwashing. While our findings reveal serious gaps, they also suggest that efforts to address greenwashing will need to engage with this complexity and design policies that examine multiple aspects of target design, implementation, and lobbying behavior in combination.

Methods

Definition of "climate pledge" greenwashing

While there is no single, universal definition or standard for greenwashing, it is broadly understood as the general act of misleading stakeholders about an organization's environmental practices or products. There is usually an intentionally deliberate nature of greenwashing, where companies use misleading communication that causes people to form "overly positive beliefs about an organization's environmental practices or products"[34]. For example, a company may use vague or ambiguous language that can be misinterpreted by the public, or even exaggerate performance claims while only doing the bare minimum to meet regulatory standards[35]. They could even mislead shareholders and the public into thinking they are taking green action, only to engage in lobbying activities that mislead the public and policymakers[31].

The multifaceted nature of greenwashing necessitates robust frameworks to evaluate the credibility of environmental claims, especially when considering net-zero pledges. Net zero was initially formulated as a scientific concept but has since shifted to a political, social and economic target[8]. It is commonly defined as the goal of achieving a balance between anthropogenic greenhouse gas emissions and their removal by sinks in the latter half of the century, a global target established in the Paris Agreement to help limit global temperature rise to well below 2 °C, with efforts to stay as close to 1.5 °C above pre-industrial levels as possible[36]. Following the IPCC's Special Report on Global Warming of 1.5 °C[1], countries began adapting this global goal to national targets, with the UK legislating a net-zero emissions goal by 2050 in 2019[37]. In the Fall of 2020, the United Nations Climate Secretariat and the COP26 Climate Champions launched the Race to Zero (RtZ) campaign to galvanize non-state actors to set their own net-zero pledges.

While the RtZ campaign successfully encouraged a range of companies and subnational governments to commit to net-zero pledges, concerns about the credibility of these pledges quickly surfaced. In response, UN Secretary-General Antonio Guterres announced the formation of a High-Level Expert Group (HLEG) at the 2021 COP to help standardize definitions and guidelines for net-zero target-setting. Shortly thereafter, the RtZ established the Five "Ps" (pledge, plan, proceed, publish, and persuade) as "starting line" criteria for non-state actors' net-zero pledges, serving as a test bed for defining net-zero at the individual level[38]. However, as researchers have noted, many net-zero pledges, notably those made by non-state actors, are inconsistent with entities' actual behavior[39]. In fact, the Net Zero Tracker's 2024 stocktake report shows that only 5 percent of the Forbes 2000 public-listed companies meet the RtZ's Five Ps criteria.

Within this context, recent efforts to assess the credibility of climate commitments highlight the increased policy attention to moving beyond corporate rhetoric to measurable integrity. For instance, Green et al.[15] develop a robustness index that evaluates net-zero pledges across nine indicators, largely following the Net Zero Tracker[2] framework, including target status, target year, greenhouse gas coverage and scope, presence of interim targets, mitigation plan, reporting frequency and rigor, use of offsets, and general accountability. Similarly, Fankhauser et al.[8] outline seven attributes of credible net-zero targets, including front-loaded or near-term emission reductions, comprehensive sectoral coverage, limited reliance on removals and offsets, and alignment with equity and sociological objectives.

To address these criteria for credible net-zero pledges and the complexities related to greenwashing climate and net-zero claims, Nemes et al.[16]. provide a starting point to evaluate the quality and truthfulness of environmental claims made by various actors, including corporations. They conduct a thorough review of existing greenwashing definitions and frameworks to unify the various interpretations and theoretical perspectives,

creating a set of indicators that can be systematically assessed across 13 themes, such as exaggerated claims, vague or misleading language, and false narratives. We build on their comprehensive review, alongside the HLEG[6] and ISO[17] guidelines for net-zero, as well as the Net Zero Tracker's framework for high-integrity, credible net-zero targets[2,40]. Our framework identifies seven dimensions most directly tied to climate pledge/net-zero greenwashing:

1. No interim target—a company has no reported near or short-term interim emission targets that would indicate near-term action.
2. No Scope 3 emissions coverage—a firm's emissions reduction targets exclude Scope 3 or value-chain emissions, which in the case of most companies represent substantial contributions to their overall emissions impact[41–43].
3. No plan to achieve targets—a firm lacks a publicly available plan detailing the steps it will take to meet its stated emissions reduction goals.
4. Questionable use of carbon credits and offsets—an entity plans to rely on offsets without specifying conditions or fails to disclose whether offsets will be used.
5. Incomplete emissions coverage—a company claims a "net-zero," "GHG neutrality," or other emission targets but limits its emissions inventory to only carbon dioxide (CO_2) or does not specify which gases are covered for any mitigation target.
6. Anti-climate lobbying—a company actively engages in lobbying activity that undermines climate action.
7. Not on track to meet targets—a company is failing to make meaningful progress towards their own stated emission reduction target, suggesting it is not implementing measures that would indicate credible efforts taken to achieve its net-zero pledge.

Using this framework, we define greenwashing as 1) a claim by a company that its actions are environmentally friendly (in our context, an emissions reduction or net-zero pledge), and 2) evidence that the company is taking actions that contradict this claim, such as engaging in practices that undermine climate goals. In our dataset, we identify that a company has made a "climate claim" if it: i) appears on the Net Zero Tracker with any type of emission reduction pledge including pledges to achieve "Carbon Neutrality," "Net Zero," "Zero Emissions," specific percentage reductions for emissions, or sector-specific targets, or ii) reports at least one emissions target for any scope. We then evaluate these claims using the seven dimensions of climate claim/net-zero greenwashing outlined above, which assess the presence of interim targets, Scope 3 coverage, concrete plans, reliance on offsets, emissions inventory completeness, lobbying efforts, and actual progress toward achieving targets, describing the incidence for each one of them, as well as the overall incidence. We do not apply statistical weights to aggregate the indicators into a single index, since, as Nemes et al.[16] note, there is no agreed approach in the literature and any attempt to assign weights could be inherently subjective, whether by privileging certain core themes, inflating themes with more questions, or treating all themes equally. Additionally, since our indicators lack a dimension of intensity and instead are binary occurrences, combining them together in a single index could dilute their meaning and interpretation. Instead, we evaluate each indicator individually, examining potential corporate determinants that may be associated with different components of the greenwashing framework.

Data sources. We constructed our dataset by matching companies across three different sources: the Net Zero Tracker, CDP, and LobbyMap.

Net Zero Tracker: As of September 2024, the Net Zero Tracker evaluates the net-zero status of 4171 entities, including 198 countries, 708 states and regions in the world's largest 25 emitting countries, 1186 cities with a population greater than 500,000, and 1977 publicly-listed companies. The Net Zero Tracker utilizes publicly-available data sources in multiple languages to conduct systematic Internet searches to evaluate entities' net-zero targets against a set of standardized characteristics, such as the target year, greenhouse gas coverage, and specification of the use of offsets[40]. Although the Net Zero Tracker does not publish historical records of its database, for this study we draw on Green et al. (2024)[15], which reconstructs historical Net Zero Tracker records for countries and companies up to August 2023. Using this dataset, we assembled a subset covering the companies and variables used in our analysis as they were self-reported and recorded in 2022, thereby aligning the Net Zero Tracker information with the year of our CDP data. Where necessary, we replaced the 2024 Net Zero Tracker values with the corresponding 2022 entries for entities in our sample. Specifically, we utilized the following NZT data:

- Net-zero implementation plan
- End targets
- End target status
- Condition on the use of offsets
- Presence of interim target
- Emission scope coverage

CDP: We obtained information regarding companies' quantifiable emission reduction targets and emissions from the 2022 Global Climate Action of Cities, Regions and Companies[44] report, which evaluated data for companies disclosing to the 2022 CDP Climate Change Questionnaire from 13 major greenhouse-gas emitting countries (Argentina, Australia, Brazil, Canada, China, the European Union, India, Indonesia, Japan, Mexico, South Africa, the United Kingdom, and the United States). In total we include data for 2295 companies that disclosed a quantifiable emission reduction target and the following information:

- Emissions data and years - baseline and monitoring emissions data in tons of CO_2 or CO_2e, depending on what the company reported.
- Sector
- Targets - emission reduction percentage, target year
- Target scope coverage (i.e., Scope 1, Scope 1 and 2, Scope 1, 2, and 3, etc).
- Target status (i.e., Underway, New, Achieved, Revise)

LobbyMap: InfluenceMap's LobbyMap has developed a methodology to evaluate corporate lobbying activities related to climate policy. Grades are determined by evaluating both direct corporate actions—including official corporate reports, statements by CEOs, financial disclosures, and direct consultations with governments—and indirect influences through trade associations. Companies are given an Organization Score, which evaluates their direct engagement, and a Relationship Score, which evaluates their industry associations' activities. These both range from 0 to 100, and are combined into a Performance Band, a letter grade score that ranges from A +, indicating strong support for science-aligned climate policies, to F, indicating obstructive lobbying activities. We use LobbyMap data extracted in October 2024. Although ideally we would match the timing of the LobbyMap scores to our NZT and CDP data, which both refer to 2022, LobbyMap does not provide historical snapshots. Their scoring methodology, however, is explicitly time-weighted: evidence is fully weighted (weight = 1) for the first two years after it is collected, then discounted every year after[45]. As a result, lobbying activities since October 2022 are fully reflected in the scores we use, and activities from a year prior are entered at 75% weight, mechanically dampening the extent to which scores would change between 2022 and our extraction date.

To assess the stability of these scores over time, we compared LobbyMap Performance Bands for a random sample of 50 companies between the earliest archived snapshot (June 1, 2023) and our October 2024 extraction. Twenty-six companies' Performance Bands were unchanged, and 19 changed by only half a letter grade (e.g., from B to B +). Five companies were new additions to the LobbyMap database and therefore appear only in the later snapshot. In addition, we incorporate LobbyMap scores in our analysis as a binary "pass/fail" measure: for example, a shift from A+ to B− would not change a company's classification as passing. In our random sample, only one company's score changed enough over this period to move from failing to passing (from D+ to B). Taken together, these features

suggest that LobbyMap scores for our sample are relatively stable over 2022–2024 and that any errors introduced by this temporal mismatch are likely to be minimal.

Matching. To link companies across these different datasets, we used the ClimActor package in R[46]. We manually reviewed and corrected issues with matches to construct our final database.

Assessing greenwashing variables. We assigned a value of 1 to companies that failed any of our seven greenwashing indicators, and 0 to those that did not, creating a binary coding scheme.

No interim target or No plan: A credible net-zero or carbon neutrality pledge must go beyond a long-term goal; it requires a clear implementation plan and interim milestones. We identify potential greenwashing when a company has made an emissions reduction pledge but has neither published a plan nor set interim targets. We code these variables as potential greenwashing when Net Zero Tracker reports that a company has no plan and has no interim target. If NZT is missing data on whether a company has an interim target, we also consider them to have an interim target if they have reported to CDP at least two targets with different target years.

No Scope 3 coverage: Scope 3 emissions – those from a company's value chain—often make up the largest share of total emissions but are harder to measure and report. A company that only accounts for Scopes 1 and 2 may be significantly underreporting its impact. We code this indicator as greenwashing risk unless either: (1) NZT reports full or partial Scope 3 coverage, or (2) CDP disclosures include any target referencing Scope 3 emissions, even partially.

Questionable use of carbon credits and offsets: High-integrity pledges prioritize cutting emissions at the source, not relying on carbon offsets. We code potential greenwashing if a company either fails to disclose whether it will use offsets, or confirms offset use without imposing conditions (e.g., excluding avoided emissions or requiring environmental and social safeguards). This data is drawn from NZT offset disclosures.

Discrepancy between gases covered in target and inventory: If a company's emissions reduction target covers multiple greenhouse gases, but they only track their carbon dioxide emissions, this discrepancy reduces the credibility of their commitment. When a company's inventory either does not specify which GHGs it covers, or specifies that it covers only carbon dioxide, and they describe their end target as "Net zero," "Net negative," "Climate neutral," "Climate positive," "Zero emissions," or "GHG neutral," we code this as potential greenwashing. Data for this indicator comes from the Net Zero Tracker, since our CDP data did not include this information.

Negative lobbying record: A net-zero pledge is less credible when a company simultaneously lobbies against climate-friendly policies. To assess this, we use LobbyMap's climate policy alignment scores, which quantify how closely a company's public policy engagement aligns with Paris Agreement goals. LobbyMap tracks corporate and industry association lobbying activities globally, scoring alignment on a 0–100 scale—scores below 50% indicate misalignment, while scores above 75% suggest strong alignment. Key metrics include the Organization Score (direct corporate lobbying), Relationship Score (alignment of affiliated trade groups), and Engagement Intensity (the strategic importance of lobbying to the company). These are combined into performance bands (A+ to F), with higher grades reflecting stronger climate alignment and lower grades indicating obstructive behavior. The scoring process relies on publicly available evidence, prioritizing recent activities to ensure accuracy and transparency[45]. We code companies (600 in total) that have a LobbyMap rating of C or lower as potential greenwashing.

Lack of progress towards target: For companies that disclosed to CDP in 2022 and were assessed in the 2022 Global Climate Action for Cities, Companies, and Regions[44], we used their pro-rated target achievement (PETA) measure to evaluate progress on their company-wide or site/facility-wide targets. To assess progress, we compared the actual emissions reductions achieved by each actor in the most recent inventory year to their pro-rated emissions reduction targets. These targets were calculated using a linear trajectory from the base year to the target year, following the approach outlined by[47] and[48].

$$peta = \frac{Reduction\ achieved}{Reduction\ required} \tag{1}$$

We determined whether a company had an "on-track" target by determining whether the reduction achieved:

$$Reduction_{achieved} = Emissions_{reportingyear} - Emissions_{baseyear} \tag{2}$$

was greater than the reduction required:

$$Reduction_{required} = (Emissions_{baseyear} - Emissions_{targetyear})x\ timelapsed \tag{3}$$

We also determined the ambition of a company's emissions mitigation effort by calculating how quickly (e.g., time between base year and the target year) and how deeply a company planned to cut its emissions over time (e.g., percentage change in emissions from the base year to the target year) according to the following equation:

$$ambition = -100\left(\frac{1}{Remaining\ target\ maturity\ in\ years}\right)x\left(\frac{Emissions_{targetyear} - Emissions_{baseyear)}}{Emissions_{baseyear}}\right) \tag{4}$$

Co-occurrence and correlation between variables

We constructed a co-occurrence matrix of raw counts of potential greenwashing indicators that occur together across each company. We grouped companies by the specific combination of indicators they exhibited, creating groups of co-occurrence such as "Scope 3 and offsets" or "Offsets and lobbying," depending on whether a company was found at risk of greenwashing (i.e., coded as 1). The raw counts of companies falling into each grouping were then tallied, and additional summary variables were created to track the number of indicators flagged per company (e.g., 1, 2, 3 or 4 more more). These counts were transformed into a pair-wise co-occurrence matrix, which provided the input for a chord diagram. The chord diagram was plotted using the circlize[49] package in R. To quantify the association strength between indicators, we computed the ϕ (phi) correlation matrix using the stats[50] package and then plotted with the corrplot package (version 0.95)[51].

Analysis of greenwashing determinants

We implemented a logistic regression with Firth's bias reduction method in the R Statistical Computing Environment (version 4.4.2) using the logistf package (version 1.26.1) and the stats package (version 3.6.2), and present these results in tables created with the gtsummary package (version 2.5.0)[52].

Our main specification is a binary logistic regression model that takes the form:

$$Y = \beta_0 + \beta_1 PETA_1 + \beta_2 EndTarget_2 + \beta_3 (Revenue)_3 + \beta_4 (Region_4) + \beta_5 Sector_5 + \beta_6 Lobbying_6 + \beta_7 Ambition_7 \tag{5}$$

where:

The outcome variable Y is each of the seven types of potential greenwashing described above, or an indicator for whether any potential greenwashing exists, which takes on a 1 if any of the seven types of potential greenwashing takes on a 1.

- $PETA_1$ is the pro-rated emissions target achievement status (PETA), described above.
- $EndTarget_2$ is a company's end target's status. This is an ordered categorical variable describing the formal state of the targets. In NZT, companies' pledges are labeled as either 1) achieved, and validated by an external source, 2) self-declared as achieved but not validated, 3) in corporate strategy, 4) declared or pledged (but not yet in corporate

strategy), or 5) proposed or in discussion. In CDP data, we use the variable "Target status in reporting year" for each company's last reported target, which takes a value of either 1) achieved, 2) underway, 3) new, 4) revised, 5) expired, 6) replaced, or 7) retired. We recode these into the NZT values.

- $Revenue_3$ is the annual revenue available from NZT, which gathers this information from Forbes.
- $Region_4$ is a simplified version of the regional classification of the World Bank-based on each company's headquarters and aggregated to East Asia and Pacific, Europe and Central Asia, North America, Other/Global South.
- $Sector_5$ is one of 10 sectors, as defined from each of the different data sources.
- $Lobbying_6$ covers a company's lobbying activity. We include LobbyMap ratings as a binary indicator of whether an organization received a score of C or lower.
- $Ambition_7$ covers the ambition of a company's emission reduction efforts, as described above.

We exclude predictor variables from a model when they are also components of the outcome variable. For example, all lobbying-related variables are removed from the regression analyzing 'negative lobbying record' greenwashing. We estimated two sets of models considering the whole sample of companies with any climate pledge (Table 5) and only for those with net-zero types of pledged (Table 6).

Based on each individual model, we estimated the probability of our outcome variables for a hypothetical company, whose characteristics are taken from the modal or median values of each variable in our database. We then estimated the probability of our outcome variables for the 2.5th and 97.5th percentile of a selection of continuous variables such as revenue, ambition and PETA, to identify the effect of some of these variables on the probability of greenwashing.

Data availability

Data from the Net Zero Tracker is available at http://zerotracker.net, and information from LobbyMap is available at https://lobbymap.org/LobbyMapScores. Data from CDP is not publicly available but can be requested from http://www.cdp.net.

Received: 2 June 2025; Accepted: 28 January 2026;
Published online: 07 February 2026

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Acknowledgements

This work was supported by the IKEA Foundation (Grant No. G-2010-01689). The 2022 CDP data was licensed to A. H. for the 2022 Global Climate Action from Cities, Regions, and Companies Report. The authors thank Sander Chan, Yann Robiou du Pont, Mark Roelfsema and Takeshi Kuramochi for their helpful inputs and review on earlier drafts of this work.

Author contributions

E.B. and A.H. designed study, collected and analyzed data, developed models and evaluated results. D.M. contributed to data analysis and writing. All authors contributed to writing of the manuscript.

Competing interests

The authors declare no competing interests.

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